Pollution Control Technology for Industrial Wastewater

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POLLUTION CONTROL TECHNOLOGY FOR INDUSTRIAL WASTEWATER

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POLLUTION CONTROL TECHNOLOGY
FOR INDUSTRIAL WASTEWATER

Foreword

This book provides an extensive survey of the reliability and effectiveness of 56 unit operations in industrial water pollution control. These operations include 32 generic wastewater treatment technologies, classified as preliminary, primary, secondary or tertiary, and 24 sludge treatment and disposal technologies.

Each process is briefly described by the type of control equipment required, the major variations of design, flow diagrams, and information on the following: design criteria, common modifications, typical performance, applications and limitations of the process, reliability, chemicals required for operation, residuals generated, and environmental impacts.

A summary table for most technologies is provided showing the concentrations of various pollutants in the effluents, the minimum, maximum, median, and mean removal efficiencies, and the number of data points used to generate this information. Conventional pollutants as well as EPA-categorized "priority pollutants" and "hazardous substances" are covered. Data sheets summarizing the results of tests at specific installations are also included.

The data in this book is from *Treatability Manual, Volume III, Technologies for Control/Removal of Pollutants* (EPA 600/8-80-042c), issued by the Office of Research and Development of the U.S. Environmental Protection Agency, July 1980.

The information reviewed here should be extremely useful to engineers, management personnel, and others involved with regulatory requirements, guidelines, and decisions.

The table of contents will serve as a subject index and provide easy access to the information contained in the book. A complete set of references has been included.

In order to keep the price of this large and extensive book to a reasonable level, it has been reproduced by photo-offset directly from the original report and the cost savings passed on to the reader. Due to this method of publishing, certain portions of the report may be less legible than desired.

Acknowledgements

The sheer size and comprehensiveness of this document should make it obvious that this had to be the effort of a large number of people. It is the collection of contributions from throughout the Environmental Protection Agency, particularly from the Office of Enforcement, Office of Water and Hazardous Materials and the Office of Research and Development. Equally important to its success were the efforts of the employees of the Aerospace Corporation, Mathtech, Inc., and the Monsanto Research Corporation who participated in this operation.

No list of the names of everyone who took part in the effort would in any way adequately acknowledge the effort which those involved in preparing this volume made toward its development. Equally difficult would be an attempt to name the people who have made the most significant contributions both because there have been too many and because it would be impossible to adequately define the term "significant." This document exists because of major contributions by the contractor's staff and by members of the following:

Effluent Guidelines Division
Office of Water and Waste Management

Permits Division
Office of Water Enforcement

National Enforcement Investigation Center
Office of Enforcement

Center for Environmental Research Information

Municipal Environmental Research Laboratory

Robert S. Kerr Environmental Research Laboratory

Industrial Environmental Research Laboratory
Research Triangle Park, NC

Industrial Environmental Research Laboratory
Cincinnati, OH
Office of Research and Development

Table of Contents

1. Introduction

This volume presents performance data and related technical information for 56 unit operations used in industrial water pollution control. These 56 unit operations include 24 sludge treatment and disposal technologies and 32 generic wastewater treatment technologies classified as preliminary, primary, secondary, or tertiary treatment. Section 2 discusses the rationale used to segregate the 32 wastewater treatment technologies into four classifications.

In Sections 3 through 8, each wastewater or sludge treatment/disposal technology is briefly described and generalized performance characteristics are given for the preliminary wastewater treatment (conditioning) and sludge processing technologies. However, emphasis is placed on the pollutant removal capabilities of the 28 primary, secondary, and tertiary wastewater treatment technologies. Both concentration and removal efficiency data are given for the following group of pollutants:

(1) Conventional pollutants[a] such as biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total organic carbon (TOC), total suspended solids (TSS), oil and grease, total phenol, total phosphorus, total Kjeldahl nitrogen (TKN), and total organic chlorine (TOCl),

(2) 129 toxic pollutants derived by EPA from the 65 "priority pollutants" listed in a Consent Agreement, Natural Resources Defense Council vs Train, 8 ERC 2120 (D.D.C. 1976),

(3) Compounds selected from the list of substances designated by EPA as hazardous under authority of Section 311 of the CWA, based on the availability of either a consensus analytical methods or one promulgated under authority of Section 204(h) of the CWA, and

(4) Other nonconventional pollutants of concern in specific industrial wastewaters.

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[a]Section 301 of the Clean Water Act defines conventional pollutants to be oil and grease, BOD, TSS, fecal coliform, and pH. The Treatability Manual lists other pollutants under the general heading "conventional pollutants" while recognizing that they are not so defined by the Clean Water Act.

The technology descriptions presented in Sections 3 through 8 discuss the primary functions and basic operating principles of each treatment process. They also discuss major design criteria, common modifications and applications, reliability and inherent technical limitations, technological status and extent of industry utilization, chemical requirements, and environmental impacts of each treatment process. However, the technology descriptions do not provide detailed information on process design or operation. They are intended for overview purposes only. Similarly, the performance characteristics given for the preliminary wastewater treatment and sludge treatment/disposal technologies are intended only as general guidelines.

Pollutant removal data for the primary, secondary, and tertiary treatment technologies are presented in two forms: plant specific data sheets and statistical summary tables. Each plant-specific data sheet lists the concentrations of various pollutants in the influent and effluent to the treatment operation and the corresponding removal efficiencies for these pollutants. When available, the following types of information are also provided.

- Point source category, subcategory and identification code of the plant discharging the waste
- Scale of the treatment operation (e.g., full scale, pilot scale, bench scale)
- Location of the treatment operation in the overall waste treatment system for the plant (e.g., primary, secondary, tertiary treatment)
- Design and operating parameters
- Reference from which the information was taken

References for the plant-specific data include Effluent Guidelines development documents and contractor reports, other EPA reports, journal articles, and conference papers. The data are reported as they appear in the original references, except that certain concentration and removal efficiency values are rounded to fewer significant figures. Conventional pollutant concentrations are reported to a maximum of three significant figures, while removal efficiencies and concentration data for the other groups of pollutants are limited to two significant figures. This convention has been adopted for formating purposes only and does not necessarily reflect the accuracy and reproducibility of the data. The confidence limits associated with individual concentration values and removal efficiencies are unknown unless otherwise noted on the data sheets.

In many cases, the concentrations of toxic organic pollutants in treatment system effluents are reported as "not detected" or "below detectable limits" in the original references and no detection limits are specified. These concentrations are also reported as "not detected" or "below detectable limits" on the plant specific data sheets.

For removal efficiency calculations, however, "nondetectable" organic pollutant concentrations are assumed to be either (a) <10 μg/L if the influent concentration exceeds 10 μg/L, or (b) less than the corresponding influent concentration if a finite influent concentration <10 μg/L is reported. These assumptions reflect EPA's experience with a draft analytical screening protocol (Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants, U.S. EPA, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268, March 1977, Revised April 1977) over the last 18 months.

In other cases, treatment system effluents have been reported to contain higher concentrations of certain pollutants than the untreated wastewaters. However, "negative removals" are not reported on the plant-specific data sheets. Where the effluent concentration for a given pollutant exceeds the corresponding influent concentration, the removal efficiency is reported as zero and treated as such in the data summarization.

The statistical summary table for each primary, secondary, and tertiary wastewater treatment technology incorporates all effluent concentration and removal efficiency data contained in the plant-specific data base for that technology. Minimum, maximum, median, and mean effluent concentrations and removal efficiencies are given for each pollutant listed on one or more of the data sheets. These statistics are intended only as general performance indicators for the treatment technologies since they do not account for differences in system design and operation, influent pollutant loadings, or the types of industrial wastewaters being treated. Median/mean effluent concentrations and removal efficiencies reported for a given treatment technology are not necessarily indicative of the technology's pollutant removal capabilities when applied to a specific industrial wastewater.

2. Technology Overview

The 56 wastewater and sludge treatment/disposal technologies addressed in this volume are divided into six groups, based on their primary functions. These are (1) wastewater conditioning, or preliminary treatment, (2) primary wastewater treatment, (3) secondary wastewater treatment, (4) tertiary wastewater treatment, (5) sludge treatment, and (6) sludge disposal. Figure 1 identifies the technologies included in each of these groups.

The four wastewater conditioning technologies are designed to prepare wastewater streams for further treatment. Screening and grit removal separate coarse materials from the waste stream to prevent damage to downstream pumps, sedimentation tank sludge collectors, and other process equipment. Equalization damps out fluctuations in hydraulic flow and pollutant loading from the plant production process, and neutralization renders acidic or basic waste streams suitable for pH sensitive treatment processes (e.g., biological treatment). Neutralization may also be used as the final step in a treatment process to meet pH standards. None of these wastewater conditioning technologies are designed to remove specific pollutants from wastewater, however.

The remaining 28 wastewater treatment technologies are arbitrarily classified as primary, secondary, or tertiary treatment based on the types of pollutants they are designed to remove. This classification procedure is adapted only for organizational purposes in this volume; it is not meant to imply that technologies classed as primary, secondary, or tertiary are always used in these treatment applications. The seven generic technologies classified as primary treatment are designed to remove suspended or colloidal materials from wastewater. Gravity oil separation, sedimentation, and gas flotation (e.g., dissolved air flotation) remove free oil and grease and suspended solids, as well as specific compounds locked in these matrices. When chemical addition (coagulants or settling aids) is used in conjunction with sedimentation or gas flotation, dispersed oil and grease and colloidal solids can also be removed. Ultrafiltration performs a similar function. Filtration is primarily used for effluent polishing, in terms of suspended solids, or as a pretreatment step for other processes that are adversely affected by suspended solids. Although these technologies are classified as primary treatment, they are not always used as the initial treatment step. For example, filtration is frequently used as a tertiary operation following secondary clarification. Ultrafiltration and sedimentation or gas flotation with chemical addition are often used as "secondary" treatment processes, following gravity oil separation for free oil removal. In some cases, these processes may also be applied for tertiary treatment. Lime treatment of secondary effluents for phosphorus removal is an example of this type of application.

The technologies classified as secondary treatment include two physical/chemical processes and four generic biological processes. For performance data summary purposes, lagooning is subdivided according to the types of biological activity involved and other basic operating principles (e.g., mechanical vs. natural aeration).[a] These technologies are classified as secondary treatment because their primary function is to remove dissolved organic materials from wastewater. These processes are normally preceded by primary treatment for suspended solids removal, particularly steam stripping and solvent extraction where contactor fouling can be a major problem.

Steam stripping and solvent extraction are frequently used in the chemical industry, but usually in the production process itself rather than for wastewater treatment. These processes are most applicable for treatment of concentrated waste streams containing organic materials that are refractory to biological oxidation. Steam stripping may also be used as a pretreatment step for activated sludge or other biological treatment processes to remove volatile organics that evaporate before biological oxidation occurs.

Activated sludge processes, trickling filters, and lagoons are by far the most common treatment processes for dissolved organic materials, primarily because they are less expensive and easier to operate than physical/chemical treatment alternatives. Rotating bilogical contactors, relatively new innovations in the wastewater treatment field, are also being used in some applications.

The 15 technologies classifed as tertiary wastewater treatment processes are primarily designed to remove dissolved organics or inorganics that are refractory to primary and secondary treatment. Processes such as activated carbon adsorption, chemical oxidation, and ozonation may be used in secondary treatment applications, but they tend to be more expensive than biological treatment. However, the use of powdered activated carbon in conjunction with the activated sludge process is gaining favor

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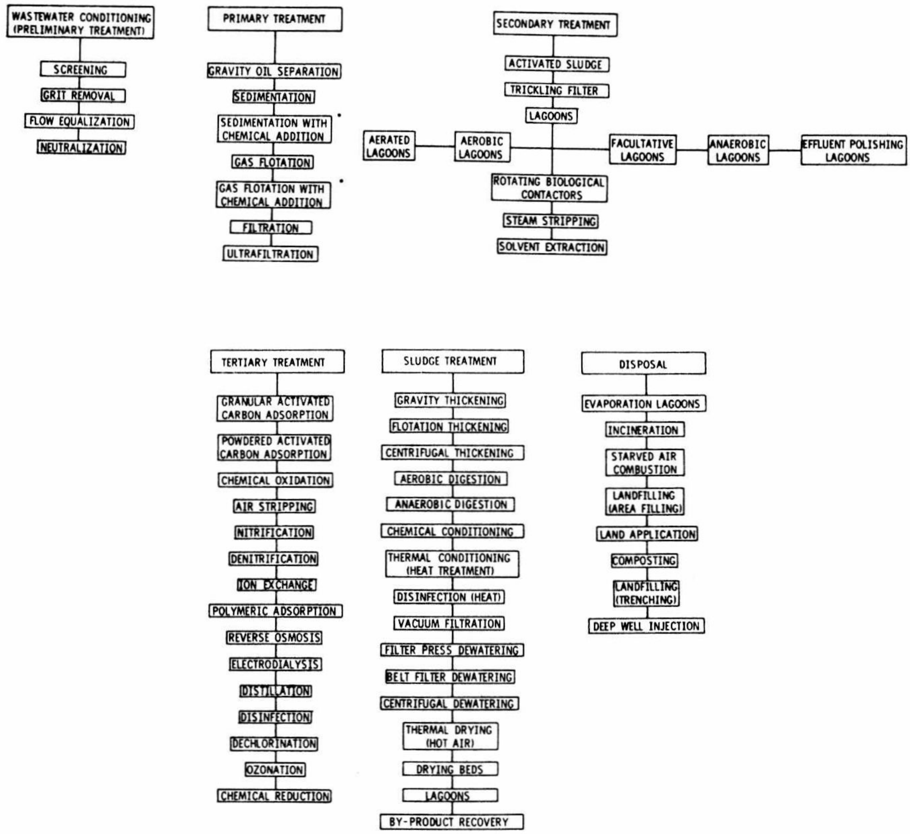
[a]Sedimentation with chemical addition and gas flotation with chemical addition are also subdivided for data summarization according to the type(s) of coagulants or settling aids used.

as a method to improve refractory organic removal and secondary settling.

For wastewaters containing little or no suspended or biodegradable organic material, tertiary technologies may be used to remove selected materials from the raw waste stream without recourse to standard primary or secondary treatment processes. Examples of this include chromate removal from cooling tower blowdown via ion exchange or reverse osmosis. In most wastewater treatment applications, however, primary and secondary treatment processes are used upstream from the tertiary technologies listed in Figure 1. Most of these tertiary technologies are rendered uneffective or more expensive to operate by high suspended solids or organic loadings.

The 15 sludge treatment technologies include various thickening, digestion, dewatering, disinfection, and other conditioning alternatives. Many of these processes are used consecutively in wastewater treatment plants; thickening, digestion, and dewatering for example. In general, they are designed to render sludge suitable for a particular disposal alternative and/or to facilitate handling and transportation.



* SUBCLASSIFICATIONS FOR PERFORMANCE DATA SUMMARY PURPOSES ARE BASED ON THE TYPES OF COAGULANTS OR SETTLING AIDS USED.

Figure 1. Treatment technology overview.

3. Wastewater Conditioning (Preliminary Treatment)

3.1 SCREENING [1]

3.1.1 Function

Screening is used to remove coarse and/or gross solids from untreated wastewater before subsequent treatment.

3.1.2 Description

There are two major types of screening processes. These are termed wedge wire screening and rotating horizontal shaft screening.

Wedge Wire Screen. A wedge wire screen is a device onto which wastewater is directed across an inclined stationary screen or a drum screen of uniform sized openings. Solids are trapped on the screen surface while the wastwater flows through the openings. The solids are moved either by gravity (stationary) or by mechanical means (rotating drum) to a collecting area for discharge. Stationary screens introduce the wastewater as a thin film flowing downward with a minimum of turbulence across the wedge wire screens, which is generally in three sections of progressively flatter slope. The drum screen employs the same type of wedge wire wound around its periphery. Wastewater is introduced as a thin film near the top of the drum and flows through the hollow drum and out the bottom. The solids retained by the peripheral screen follow the drum rotation until removed by a doctor blade located at about 120° from the introduction point. Wedge wire spacing can be varied to best suit the application. For municipal wastewater applications spacings are generally between 0.01 and 0.06 inches (0.25 to 1.5 mm). Inclined screens can be housed in stainless steel or fiberglass; wedge wires may be curved or straight; the screen face may be a single multi-angle unit, three separate multi-angle pieces, or a single curved unit. Rotary screens can have a single rotation speed drive or a variable speed drive.

Rotating Horizontal Shaft Screen. A rotating horizontal shaft screen is an intermittently or continously rotating drum covered with a plastic or stainless steel screen of uniform sized openings, installed and partially submerged in a chamber. The chamber is designed to permit the entry of wastewater to the interior of the drum and collection of filtered (or screened) wastewater from the exterior side of the drum. With each revolution, the solids are flushed by sprays from the exposed screen surface into a collecting trough. Coarse screens have openings of less than 1/4 inch. Screen with openings of 20 to 70 microns are called microscreens or microstrainers. Drum diameters are 3 to 5 feet with 4- to 12-feet lengths.

3.1.3 Technology Status

Wedge Wire Screen. Wedge wire screens have been used in industry since 1965 and in municipal wastewater treatment since 1967. There are over 100 installations to date.

Rotating Horizontal Shaft Screen. Rotating horizontal shaft screens are in widespread use for roughing pretreatment and for secondary biological plant effluent polishing.

3.1.4 Applications

Wedge Wire Screen. Stationary and rotary drum screens are ideally suited and usually employed after bar screens and prior to grit chambers. They have also been employed for primary treatment, scum dewatering, sludge screening, digester cleaning, and storm water overflow treatment.

Rotating Horizontal Shaft Screen. Used for removal of coarse wastewater solids from the wastewater treatment plant influent after bar screen treatment with screen openings 150 microns to 0.4 inches; also used for polishing activated sludge effluent with screen openings 20 to 70 microns.

3.1.5 Limitations

Wedge Wire Screen. Require regular cleaning and prompt residuals disposal.

Rotating Horizontal Shaft Screen. Dependence on pretreatment and inability to handle solids fluctuations in tertiary applications; reducing speed of rotation of drum and less frequent flushing of screen has resulted in increased removal efficiencies, but reduced capacities.